

**Charm Physics --  
The Theory Case for a New  
Generation of Experiments**

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### The Stage:

within SM; charm decays 'dull'

- $|V_{cs}| \& |V_{cd}|$  well known via KM unitarity

- slow  $D^0 - \bar{D}^0$  oscill., small  $\Delta m^2$ ,  
tiny BR's for rare decays

→ probe QCD in novel environment  
under controlled lab. conditions  
⇒ apply in beauty decays

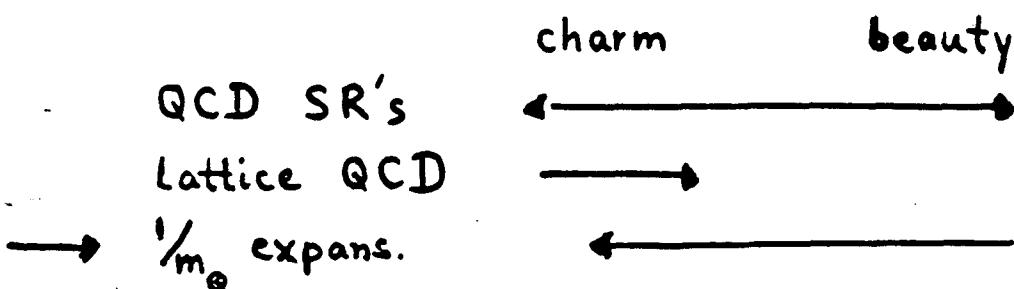
- searches for New Physics with small SM bkgnd.

### Benchmarks:

reach SM level for  $D^0 - \bar{D}^0$  oscill. & CP

### Tools:

2<sup>nd</sup> generation theoret. technologies



## Outline

I Worthy Open Questions

II Answers Expected from On-going & Approved Experim.

III Benchmarks for Further Studies

IV The New Generation

Disclaimer: will not discuss charm production

(leading particle effects,  
associated & diffractive product.  
correlations  
... )

## I Open Questions Worthy of an Answer

### (A) Lifetimes

	QCD predict. ( $1/m_c$ exp.)	data '94	data '93
$\frac{\tau(D^+)}{\tau(D^0)}$	$\sim 2$		$2.50 \pm 0.05$
$\frac{\tau(D_s)}{\tau(D^0)}$	$1 \pm \text{few} \times 0.01$		$1.13 \pm 0.05$
$\frac{\tau(\Xi_c^+)}{\tau(\Lambda_c)}$	$\sim 1.3$	$1.68 \pm 0.5$	$2.0 \pm 0.7$
$\frac{\tau(\Xi_c^+)}{\tau(\Xi_c^0)}$	$\sim 2.8$	$2.46 \pm 0.75$	$4.0 \pm 1.5$

$$\frac{\tau(D^+, D_s)}{\tau(D^0)} = 1 + \mathcal{O}(1/m_c^3), \quad \frac{\tau(\Lambda_c, \Xi_c)}{\tau(D^0)} = 1 + \mathcal{O}(1/m_c^2)$$

motivation for further study

- disentangle non-spectator effects  
 $\sim \mathcal{O}(1/m_c^2, 1/m_c^3)$

- gauge indirectly  $\mathcal{O}(1/m_c^4)$  terms

'Charm decays as nature's microscope  
for  
beauty decays'

## (B) SL Decays

### i total widths

$$BR_{SL}(D^+) = 17.2 \pm 1.9 \% \quad \sim MKIII \quad \sigma \sim 11 \%$$

$$BR_{SL}(D^0) = \begin{cases} 7.7 \pm 1.2 \% & \cdot \quad \sigma \sim 16 \% \\ 6.97 \pm 0.18 \pm 0.30 \% & CLEO \quad \sigma \sim 5 \% \end{cases}$$

$$BR_{SL}(D_s) = ?$$

$$BR_{SL}(\Lambda_c, \Xi_c) = ?$$

why

- $\Gamma_{SL}(D) \neq \Gamma_{SL}(\Lambda_c)$

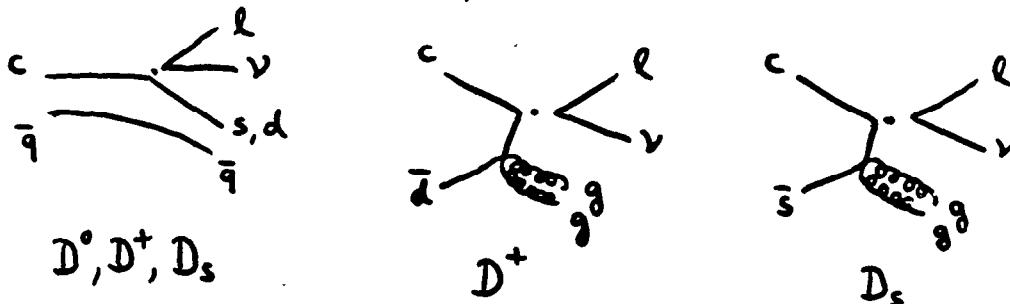
- calibration point for

$$\Gamma_{SL}(B) \Rightarrow |V(cb)|$$

### ii inclusive lepton spectra

$$\frac{d\Gamma}{dE_\ell} (H_c \rightarrow \ell X) \Rightarrow |V(cd)|, |V(cs)|$$

$H_c = D^0, D^+, D_s, \Lambda_c$



why

calibration for

$$\frac{d\Gamma}{dE_\ell} (B \rightarrow \ell X) \Rightarrow |V(cb)|, |V(u\bar{b})|$$

### (iii) exclusive SL decays

$\frac{d\Gamma}{dq^2} (D \rightarrow l\nu K^{(\pi)}, l\nu \pi/g)$  measure rather than assume it

why

- compare with lattice QCD & QCD SR's

- some lessons for  $B \rightarrow l\nu D^{(\pi)}, l\nu \pi/g$

### (C) Exclusive NL Decays

#### i) absolute BR

at present:  $\delta BR(D \rightarrow f) \sim 5-10\%$

$\delta BR(D_s \rightarrow f) \sim 30\% ?$

$\delta BR(\Lambda_c \rightarrow f) \sim ?$

$\delta BR(\Xi_c \rightarrow f) \sim ?$

why

- engineering input

-  $B_{(s)} \rightarrow l\nu D_{(s)}^{(\pi)}$  }  
 $\Lambda_b \rightarrow l\nu \Lambda_c$  }  $\Rightarrow |V(cb)| \& \text{formfactors}$   
 $BR(D_{(s)}, \Lambda_c)$

- charm content in  $B$  decays.

expect  $\sim 1.15 - 1.3$  charm/ $B$  decay

observe  $\sim 1$  charm/ $B$  decay  $BR(D_s, \Lambda_c) = ?$

## (ii) 2 body modes

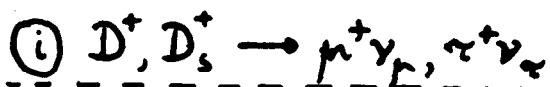
'BSW' description (factorization etc.)

separately for Cabibbo allowed, 1x and 2x suppressed  
modes of  $D, D_s, \Lambda_c$

why

- uncover/identify deviations from factorization
  - extract info on strong phase shifts
- better predictions on direct  $\bar{K}^0 \rightarrow \pi^+ \nu_\mu \bar{\nu}_e$  (see later)

## (D) Rare Decays



	QCD predict.	data	
$f_D$	$200 \pm 30$ MeV	$< 290$ MeV	90% C.L. Mk III
$f_{D_s}$	$235 \pm 35$ MeV	$232 \pm 45 \pm 20 \pm 48$ MeV	WA 75
		$344 \pm 37 \pm 52 \pm 42$ MeV	CLEO
		[for $\text{BR}(D_s \rightarrow \psi \pi) = 3.7\%$ ]	
$\frac{f_{D_s}}{f_D}$	$1.15 \div 1.2$		

why

- probe QCD

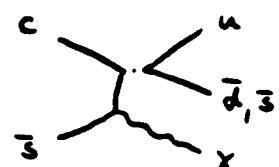
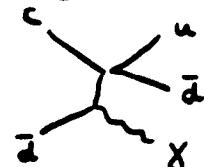
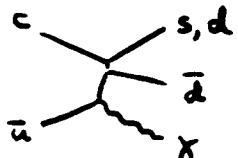
- calibrate predictions for  $f_B, f_{B_s}$

$$\textcircled{1} \quad D \rightarrow \gamma K^*, \gamma g/\omega; D_s \rightarrow \gamma g$$

nothing known

why

- per se not exciting



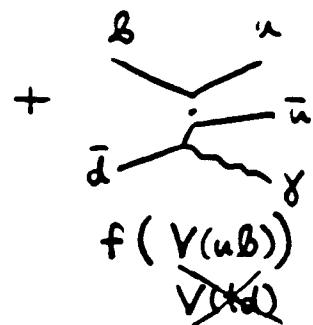
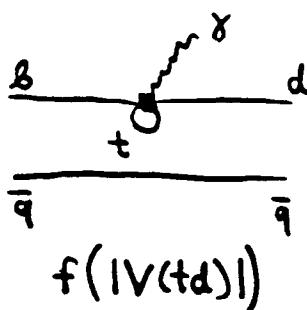
$$D^0 \rightarrow \gamma K^*/g/\omega \quad D^+ \rightarrow \gamma g^+$$

$$D_s^+ \rightarrow \gamma g^+/K^{*+}$$

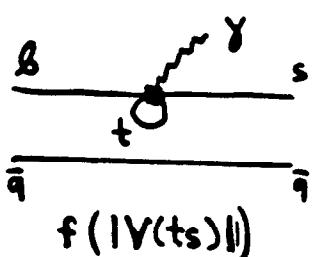
$$BR(D \rightarrow \gamma K^*) \sim 10^{-5} - 10^{-4}$$

- calibration for extraction of  $|V(td)|$

$$\Gamma(B \rightarrow \gamma g/\omega)$$

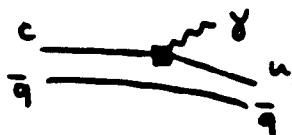


$$\Gamma(B \rightarrow \gamma K^*)$$



$$f(|V(ts)|)$$

- NP: non-minimal SUSY

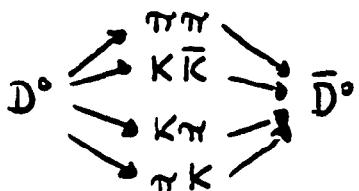


$$\frac{\Gamma(D \rightarrow \gamma g/\omega)}{\Gamma(D \rightarrow \gamma K^*)} \neq \tan^2 \theta_c \quad \left. \right\} \exists \text{ of NP}$$

(iii) Likewise for  $D \rightarrow l^+ l^- K^{(*)}/\pi/\eta$

### (E) $D^0 - \bar{D}^0$ Oscill.

$$\text{SM: } \tau_D \equiv \frac{\Gamma(D^0 \rightarrow l^- X)}{\Gamma(D^0 \rightarrow l^+ X)} \sim \Theta(10^{-4})$$



LD dynamics in SM!

$$\tau_D \leq 3.7 \times 10^{-3} \quad 90\% \text{ C.L. E691}$$

$$\leq 4.7 \times 10^{-3} \quad \text{E791 } (\frac{1}{3} \text{ data set})$$

why

NP could generate  $\tau_D$  up to  $\sim 0.5\%$

## (F) ~~CP~~

### i Direct ~~CP~~

(a) total rates

$$\Gamma(D \rightarrow f) \text{ vs. } \Gamma(\bar{D} \rightarrow \bar{f})$$

mode	measured asymm.	90% C.L. level
$D^0 \rightarrow K^+ K^-$	$0.024 \pm 0.084$	$-11\% < A_{CP} < 16\%$
	$0.071 \pm 0.065$	$-3.6\% < A_{CP} < 17.8\%$
$D^+ \rightarrow K^- K^+ \pi^+$	$-0.031 \pm 0.068$	$-14\% < A_{CP} < 8.1\%$
$D^+ \rightarrow \bar{K}^0 K^+$	$-0.12 \pm 0.13$	$-33\% < A_{CP} < 9.4\%$
$D^+ \rightarrow \phi \pi^+$	$0.066 \pm 0.086$	$-7.5\% < A_{CP} < 21\%$
$D^0 \rightarrow K_s \phi$	$-0.005 \pm 0.067$	$-11.5\% < A_{CP} < 10.5\%$
$D^0 \rightarrow K_s \pi^0$	$-0.011 \pm 0.030$	$-6\% < A_{CP} < 3.8\%$

why

- SM effects in Cabibbo supp. modes  $\leq O(0.1\%)$

- NP " " " " " maybe  $\leq O(1\%)$

(B) T odd correlations

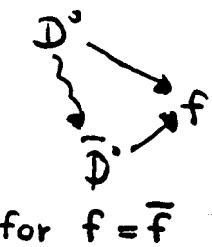
e.g.:  $D^+ \rightarrow K^+ K^- \pi^+ \pi^0$  vs.  $D^- \rightarrow K^+ K^- \pi^- \pi^0$

$$N_{\pi\pi}^{\oplus} \equiv \langle \vec{p}_{\pi\oplus} \cdot (\vec{p}_{K^+} \times \vec{p}_{K^-}) \rangle \text{ vs. } N_{\pi\pi}^{\ominus} \equiv \langle \vec{p}_{\pi\ominus} \cdot (\vec{p}_{K^+} \times \vec{p}_{K^-}) \rangle$$

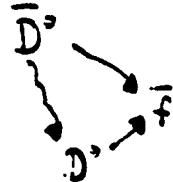
why

- nothing known
- could be larger effects

ii) CP involving  $D^0 - \bar{D}^0$  oscill.



vs.



for  $f = \bar{f}$

$$\Gamma(D^0 \rightarrow f; t) = e^{-\Gamma_D t} |T(D^0 \rightarrow f)|^2 (1 - \text{Im} \frac{q}{p} \bar{g}_f \sin \Delta m_D t)$$

$$\Gamma(\bar{D}^0 \rightarrow f; t) = e^{-\Gamma_{\bar{D}} t} |T(\bar{D}^0 \rightarrow f)|^2 (1 + \text{Im} \frac{q}{p} \bar{g}_f \sin \Delta m_{\bar{D}} t)$$

$$\bar{g}_f = \frac{T(\bar{D}^0 \rightarrow f)}{T(D^0 \rightarrow f)}$$

$$A_{CP}^f(t) \stackrel{(+)}{=} \frac{\Gamma(\bar{D}^0 \rightarrow f; t) - \Gamma(D^0 \rightarrow f; t)}{\Gamma(\bar{D}^0 \rightarrow f; t) + \Gamma(D^0 \rightarrow f; t)} \approx \frac{\Delta m_D}{\Gamma_D} \frac{t}{\tau_D} \text{Im} \frac{q}{p} \bar{g}_f$$

- $A_{CP}^f(t) \equiv 0$  if  $\Delta m_D = 0$

- $\tau_D \approx \frac{1}{2} \left( \frac{\Delta m_D}{\Gamma_D} \right)^2 : \quad \tau_D \lesssim 0.5 \cdot 10^{-2} \quad \leftarrow \frac{\Delta m_D}{\Gamma_D} \lesssim 0.1$

$\hookrightarrow A_{CP}^f(t) \lesssim 0.1 \times \frac{t}{\tau_D} \times \text{Im} \frac{q}{p} \bar{g}_f$

why - ~~0.16~~  $0.16 \geq |A_{CP}^{K^+ K^-}| = \frac{\Delta m_D}{\Gamma_D} \cdot \text{Im} \frac{q}{p} \bar{g}_{K^+ K^-}$

- SM:  $\frac{\Delta m_D}{\Gamma_D} \sim \mathcal{O}(10^{-2}) ; \text{Im} \frac{q}{p} \bar{g}_f \lesssim \mathcal{O}(10^{-2})$

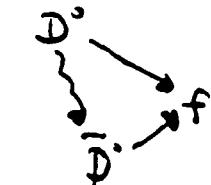
$\left\{ A_{CP}^f(t) \lesssim 10^{-4} \right.$

- NP:  $\frac{\Delta m_D}{\Gamma_D} \approx 0.1 ; \text{Im} \frac{q}{p} \bar{g}_f \sim \mathcal{O}(0.1)$

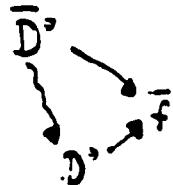
i.e.  $A_{CP}^f(t) \sim 1\%$  conceivable

'~zero bkgd. search for NP!'

## ④ CP involving $D^0 - \bar{D}^0$ oscill.



vs.



for  $f = \bar{f}$

$$\Gamma(D^0 \rightarrow f; t) = e^{-\Gamma_D t} |T(D^0 \rightarrow f)|^2 (1 - \text{Im} \frac{q}{p} \bar{s}_f \sin \Delta m_D t)$$

$$\Gamma(\bar{D}^0 \rightarrow f; t) = e^{-\Gamma_D t} |T(\bar{D}^0 \rightarrow f)|^2 (1 + \text{Im} \frac{q}{p} \bar{s}_f \sin \Delta m_D t)$$

$$\bar{s}_f = \frac{T(\bar{D}^0 \rightarrow f)}{T(D^0 \rightarrow f)}$$

$$A_{CP}^f (\pm) \equiv \frac{\Gamma(\bar{D}^0 \rightarrow f, t) - \Gamma(D^0 \rightarrow f, t)}{\Gamma(\bar{D}^0 \rightarrow f, t) + \Gamma(D^0 \rightarrow f, t)} \approx \frac{\Delta m_D}{\Gamma_D} \frac{t}{\tau_D} \text{Im} \frac{q}{p} \bar{s}_f$$

- $A_{CP}^f(t) \equiv 0$  if  $\Delta m_D = 0$

- $\tau_D \approx \frac{1}{2} \left( \frac{\Delta m_D}{\Gamma_D} \right)^2 : \quad \tau_D \lesssim 0.5 \cdot 10^{-2} \quad \left\{ \frac{\Delta m_D}{\Gamma_D} \lesssim 0.1 \right.$

↳  $A_{CP}^f(t) \lesssim 0.1 \times \frac{t}{\tau_D} = \text{Im} \frac{q}{p} \bar{s}_f$

why - ~~0.16~~  $0.16 \geq |A_{CP}^{K^+ K^-}| = \frac{\Delta m_D}{\Gamma_D} \cdot \text{Im} \frac{q}{p} \bar{s}_{K^+ K^-}$

- SM:  $\frac{\Delta m_D}{\Gamma_D} \sim O(10^{-2}) ; \text{Im} \frac{q}{p} \bar{s}_f \lesssim O(10^{-2})$

$\left\{ A_{CP}^f(t) \lesssim 10^{-4} \right.$

- NP:  $\frac{\Delta m_D}{\Gamma_D} \lesssim 0.1 ; \text{Im} \frac{q}{p} \bar{s}_f \sim O(0.1)$

i.e.  $A_{CP}^f(t) \sim 1\%$  conceivable

'~zero bkgd. search for NP ?'

## II Answers Expected from On-going & Approved Experim.

F.T. experim. at FNAL (& CERN)

CLEO

BES

SLAC/KEK asymm. B factories

- more precise data on  $\tau(D_s)$  &  $\tau(\Xi_c^{0,+})$
- $\Gamma(D_s \rightarrow lX), \frac{d\Gamma}{dE_l}(D_s \rightarrow lX), BR(D_s \rightarrow \phi\pi)$  (BES)
- $\delta BR(D \rightarrow K\pi, K\pi\pi) < 5\%$
- $BR(\Lambda_c \rightarrow p K\pi)$  via  $\Sigma_c \rightarrow \Lambda_c \pi$  ?
- $\delta f_D, \delta f_{D_s} \lesssim 20\%$
- mapping out DCSD of D &  $D_s$  mesons
- 'BSW' type analysis separately to Cabibbo allowed, 1x and 2x supp. decays of D,  $D_s$  (&  $\Lambda_c$ ?)
- detailed studies of exclusive SL decays of D,  $D_s$ ,  $\Lambda_c$
- $D^0 - \bar{D}^0$  oscill. down to  $\tau_D \sim 0(10^{-4})$  ?
- CP asymm. down to a few %

### III Benchmarks f. Further Studies

questions left without (satisfactory) answers

- absolute BR's for  $D_s, \Lambda_c, \Xi_c$  decays  
with  $\delta \text{BR} \leq 10\%$   
 $[\delta \text{BR}(D^0, D^+) \sim 0(1\%) ?]$
- $\tau(\Xi_c^{+0})$  with  $\delta \tau(\Xi_c^{+0}) \leq 5\%$   
 $\tau(\Omega_c)$  with  $\delta \tau(\Omega_c) \leq 10\%$
- $\Gamma(D_s \rightarrow l X), \Gamma(\Lambda_c \rightarrow l X)$  with  $\delta \Gamma_{SL}(D_s, \Lambda_c) \leq 5\%$
- $\frac{d\Gamma}{dE_\ell}(D/D_s/\Lambda_c \rightarrow l X) \Rightarrow |V(cd)|$  with  $\delta |V(cd)| \leq 10\%$
- $\Gamma(D^+/D_s^+ \rightarrow \mu^+ \nu)$  with  $\delta \Gamma \leq 10\%$
- $\text{BR}(D \rightarrow \gamma K^*)$  with  $\text{BR} \sim 10^{-5} - 10^{-4}$   
 $\text{BR}(D \rightarrow \gamma g/\omega) \quad .. \quad \text{BR} \sim 10^{-6} - 10^{-5}$
- $\text{BR}(D \rightarrow l^+ l^- K^{(*)}/\pi l g/\omega)$  with  $\text{BR} \sim 10^{-7} - 10^{-5} ?$

'charm decays as a QCD lab'

' search for NP '

- $R_\gamma \equiv \frac{BR(D \rightarrow \gamma \rho/\omega)}{BR(D \rightarrow \gamma K^*)}$  with  $\delta(|R_\gamma - t g^2 \theta_c|) \approx 50\%$ .

- $D^0 - \bar{D}^0$  oscill. down to  $r_D < 10^{-4}$  ?

- ~~CP~~

- CP asymm. in  $D^0 - \bar{D}^0$  oscill.

SM: 
$$\left. \begin{aligned} \frac{\#(l^+ l^+) - \#(l^- l^-)}{\#(l^+ l^+) + \#(l^- l^-)} &\leq 10^{-3} \\ \frac{\#(l^\pm l^\pm)}{\#(l^+ l^-)} &< 10^{-3} \end{aligned} \right\} \text{academic}$$

- CP asymm. involving  $D^0 - \bar{D}^0$  oscill.

$$\Gamma(D^0 \rightarrow \frac{K^+ K^-}{\pi^+ \pi^-}, K_S \pi^0; t) \text{ vs. } \Gamma(\bar{D}^0 \rightarrow \frac{K^+ K^-}{\pi^+ \pi^-}, K_S \pi^0; t)$$

SM: asymm.  $\leq \mathcal{O}(10^{-4})$

NP: could be as large as  $\mathcal{O}(1\%)$

- direct ~~CP~~

Ⓐ  $\Gamma(D \rightarrow S=0) \text{ vs. } \Gamma(\bar{D} \rightarrow S=0)$

SM: asymm.  $\leq \mathcal{O}(10^{-3})$  (see below)

NP: could be  $\leq 1\%$

Ⓑ  $\Gamma(D \rightarrow S=-1) \text{ vs. } \Gamma(\bar{D} \rightarrow S=+1)$

SM: asymm.  $\approx 0$  [ $\exists$  a single amplit. only!]

NP: "  $\sim \mathcal{O}(1\%)$

Ⓒ  $\Gamma(D \rightarrow S=+1) \text{ vs. } \Gamma(\bar{D} \rightarrow S=-1)$

SM: asymm.  $\approx 0$

NP: "  $\sim \mathcal{O}(10\%)$  !

Ⓓ CP asymm. in final state distrib., Dalitz plots etc.

have assumed

$D/D_s \rightarrow PP, PV, VV$  already done well

- with {
- some lessons on QCD: 'factorization' only approxim of non-universal validity
  - significant implications for predicting size of (mainly) direct  $\bar{C}R$

$$T(D \rightarrow f) = e^{i\alpha} e^{i\varphi_1} \partial R_1 + e^{i\alpha_2} e^{i\varphi_2} \partial R_2$$

$$T(\bar{D} \rightarrow \bar{f}) = e^{i\alpha} e^{-i\varphi_1} \partial R_1 + e^{i\alpha_2} e^{-i\varphi_2} \partial R_2$$

$$|T(D \rightarrow f)|^2 - |T(\bar{D} \rightarrow \bar{f})|^2 = 4 \sin(\alpha, -\alpha_2) \sin(\varphi, -\varphi_2) \partial R_1 \partial R_2$$

comprehensive analysis of  $D/D_s \rightarrow PP, PV, VV$

} info on  $\partial R_1, \partial R_2; \alpha_1, \alpha_2$   
 not small for D decays

$$\begin{aligned} |T(D \rightarrow f)|^2 &= \partial R_1^2 + \partial R_2^2 + 2 \cos(\alpha, -\alpha_2) \cos(\varphi, -\varphi_2) \partial R_1 \partial R_2 \\ &\quad + 2 \sin(\alpha, -\alpha_2) \sin(\varphi, -\varphi_2) \partial R_1 \partial R_2 \end{aligned}$$

## IV The Next Generation - for the Next Millennium

### (A) CHARM 2000

	statistics	systematics
$\tau(\Xi_c^{+,0}), \tau(\Omega_c)$	//	✓
$D/D_s^+ \rightarrow \rho^+ \nu$	//	?
$D \rightarrow \gamma K^*, \gamma \eta/\omega$	//	??
$D \rightarrow \ell^+ \ell^- K^{(*)}/\pi/\eta$	//	?
absolute BR's	✓	??
$\frac{d\Gamma}{dE_\ell} (H_c \rightarrow \ell X)$		?
$D^0 - \bar{D}^0$ oscill. $\tau_D < 10^{-4}$	✓	?
$\Delta P \gtrsim 0.1\%$	//	?

## (B) $\tau$ -charm Factory

apart from lifetimes  $\tau$ -c-F can do it all -

in principle and at a price

clean measurements  $\Leftarrow$  no parasitic measurements

Menu

### ① $\psi^* \rightarrow D\bar{D}$

- absolute BR's with  $\delta BR(D) \sim 0(1\%)$
- $BR(D \rightarrow \ell X)$
- $\frac{d\Gamma}{dE_\ell}$
- $D \rightarrow \gamma K^*/\pi/\omega$
- $D^+ \rightarrow \mu\nu$
- $D^0 - \bar{D}^0$  oscill.
- direct CP

### ② $e^+e^- \rightarrow D^0 \bar{D}^0 + D^0 \bar{D}^0$ $L\bar{D}^0\gamma L D^0\gamma$

- $D^0 - \bar{D}^0$  oscill.
- CP involving  $D^0 - \bar{D}^0$  oscill.

### ③ $e^+e^- \rightarrow D_s \bar{D}_s$

- absolute BR
- $BR(D_s \rightarrow \ell X)$
- $d\Gamma/dE_\ell$
- $D_s^+ \rightarrow \mu^+\nu$
- $D_s \rightarrow \gamma g$
- direct CP

④  $e^+e^- \rightarrow \Lambda_c \bar{\Lambda}_c$

- absolute BR
- $BR(\Lambda_c \rightarrow lX)$
- $d\Gamma/dE_l$

⑤  $e^+e^- \rightarrow \Xi_c^+ \Xi_c^-, \Xi_c^0 \bar{\Xi}_c^0$

- absolute BR
- $BR(\Xi_c \rightarrow lX)$

+ background runs

## Conclusions

⇒ major case for a significant new initiative  
in charm physics

one candidate:  $\tau$ -charm factory.

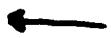
primary purpose of  $\tau$ -c-F.

study QCD in novel environment under controlled lab.  
conditions

- charm decays
- $\tau$  "
- charmonium spectroscopy & transitions
- light quark / gluonia spectroscopy

why bother?

- intrinsic interest
- calibrate tools for beauty decays



main items on charm agenda

- absolute BR's for  $D, D_s, \Lambda_c$
- $\Gamma_{SL}(D, D_s, \Lambda_c)$
- $\frac{d}{dE_\ell} \Gamma(D, D_s, \Lambda_c \rightarrow \ell X)$
- $D^+, D_s^+ \rightarrow \mu^+ \nu$
- $D \rightarrow \gamma K^*/\pi/\omega$

(i) Can it be done without  $\tau$ -c-F.?

(ii) " " " " at  $\tau$ -c-F.?

secondary purpose of  $\tau$ -c-F.

search for NP

- $\tau$  decays:  $V+A$ , 2<sup>nd</sup> class currents ...
- charm decays

most significant item on agenda

CP

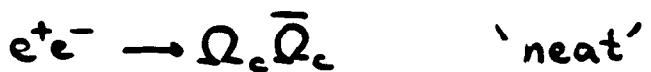
- CP asymm. involving  $D^0 - \bar{D}^0$  oscill.  
SM:  $\approx 0$   
NP:  $\lesssim$  few %
- direct CP in Cabibbo allowed D decays  
SM:  $\approx 0$   
NP:  $\leq O(1\%)$
- direct CP in 2x Cabibbo suppr. D decays  
SM:  $\approx 0$   
NP:  $\leq 10 - 20\%$
- direct CP in 1x Cabibbo suppr. D decays  
SM:  $\lesssim O(0.1\%)$   
NP:  $\lesssim$  few %

caveat: fishing expedition with no useful lower bound  
on size of fish !

can  $\tau$ -c- $\Xi$  provide answers?

benchmarks/challenges:

- energy reach



- statistics/systematics

- enough Lumi ... to get through menu

- CP asymm.

- ① down to  $O(0.1\%)$  in Cabibbo allowed & 1x supp. decays

- ② down to  $O(1\%)$  in final state distrib.

- ③ down to  $O(1\%)$  in DCSD